

population, resulting in a mean effective dose of 0,055 mSv per caput. The contribution of NM procedures to the total population dose is about 5 %.

The overall per caput effective dose for all medical imaging (X-rays + NM procedures) is therefore 1,13 mSv for EU and EFTA countries and 1,105 mSv for all European countries. These values are about half of the recent value of collective effective dose estimated in Australia and about one third of the corresponding value in the USA. However, comparing the results with an earlier estimation of population dose in Europe, in the DDM1 countries, there seems to be a trend upwards: the increase of per caput effective dose is on the average about 30 %. The overall collective effective doses of x-ray procedures per 1000 populations can be seen in Fig.1 for different countries. The relative overall collective effective doses (% of the collective effective dose of all x-ray examinations), for the main groups of plain radiography, fluoroscopy, CT and IR, are also shown. It can be seen that computed tomography yields by far the highest contribution, on the average 57,0 % (range 5,31 - 83,1 %), to the population dose in most countries, while the relative contributions of all main groups vary a lot between the countries.

A relatively low value of population dose can be a good sign for a successful implementation of the justification and optimization principles in radiation protection, but it can also be related to the lack of imaging resources. A relatively high value, vice versa, should imply considerations on whether the justification and optimization are properly implemented. While the average dose in Europe turned out to be relatively low, there are high variations of the results between countries indicating that there is a need for further studies and follow up of the trends. It is important to investigate and ensure a proper balance between local imaging resources and optimal radiation protection. The distribution of the doses between various groups of examinations and other detailed results of this study can be exploited in comparing the practices and identifying the cases requiring highest attention.

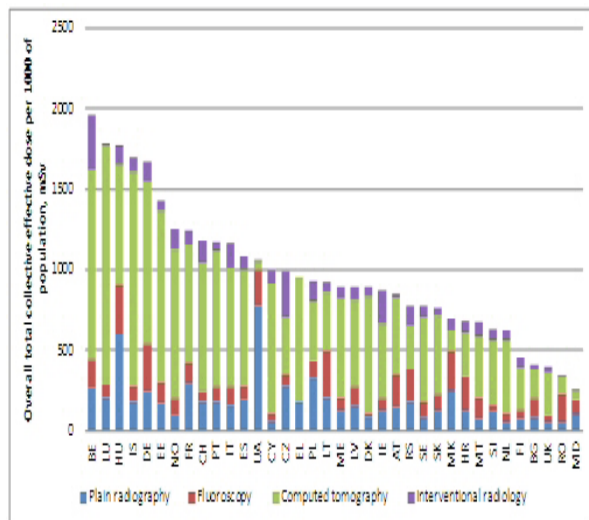


Fig. 1. Overall collective effective dose of x-ray procedures per 1000 population for different countries. The relative contributions of the four main groups (plain radiography, fluoroscopy, computed tomography and interventional radiology) are also shown.

SYMPOSIUM: NEW STRATEGIES FOR REAL-TIME INTERNAL TARGET/VOLUMETRIC IMAGING

SP-0632

Real-time telerobotic 3D ultrasound for soft-tissue guidance concurrent with beam delivery

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Managing internal anatomy motion due to physiological random or quasi-periodical processes is a critical challenge in external beam radiation therapy especially in the context of single- or few-fraction

ablative regimens for abdominal targets. Existing and emerging technologies for localizing abdominal targets during beam delivery employ tracking of implanted fiducial markers, tracking of external surrogates, or guidance via magnetic resonance images. However, these technologies cannot meet the challenge of providing real-time, volumetric, non-invasive, markerless soft-tissue image guidance to existing radiation delivery platforms.

Diagnostic ultrasound is a safe, non-ionizing, non-invasive modality widely used in image-guided cancer interventions that has significant potential to address this challenge. Modern matrix array transducers can generate real-time soft-tissue single plane (2D), cross-plane, and volumetric (3D) data thus allowing optimization of frame rate, field-of-view and image quality for the purposes of motion monitoring and tracking. Furthermore, digital navigation links that stream live data to other devices enable the development of real-time image-guidance applications on dedicated interventional workstations with no interference to the imaging process.

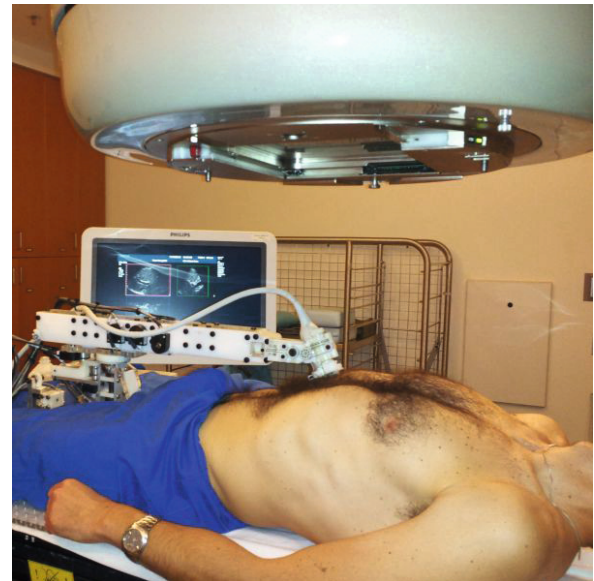


Figure 1. Robotic manipulator combined with 4D ultrasound for real-time image-guidance concurrent with beam delivery.

Based on these capabilities we are developing and evaluating a novel approach that combines robotics with diagnostic ultrasound imaging (Figure 1). It uses a customized add-on human-safe robotic manipulator to control the force and position of an abdominal probe while avoiding gantry collisions. The transducer is optically tracked to localize the ultrasound images in the coordinate system of the delivery device. Image processing techniques are implemented to monitor anatomy displacements in real time. The approach is being evaluated with regard to imaging robustness, interference with delivery devices, impact on treatment plans, localization accuracy, and temporal lag.

SP-0633

Tomosynthesis

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Cone beam CT (CBCT) integrated with a linear accelerator has provided 3D and 4D soft tissue contrast for image guided radiotherapy. While volumetric imaging has considerably improved target alignment prior to treatment delivery, it has limited capacity to monitor target alignment during treatment delivery. Tomosynthesis, on the other hand, where projection data of only a sub-arc is reconstructed into a 2½D image has the potential to increase the temporal resolution of soft tissue imaging. To that end, Tomosynthesis reconstruction can be applied to projection data acquired during VMAT (Volumetric Modulated Arc Therapy) delivery or during gantry rotation between static IMRT beams. An overview will be given of Tomosynthesis reconstruction and registration techniques. Impact of respiratory motion on Tomosynthesis image quality and possible mitigation strategies will be presented. Trade-offs between temporal resolution and spatial resolution will be demonstrated and

clinical applications exemplified. Finally, future directions will be discussed.

SP-0634

Cine cone beam CT imaging with and without prior images

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Cone beam CT (CBCT) has been widely utilized for localizing daily tumor position and patient positioning in lung cancer radiotherapy. However, due to the respiratory motion during the CBCT scan, the tumor image is blurred and may introduce inaccuracy in treatment delivery. To solve this problem, and to obtain accurate daily lung tumor motion information, we have been developing cine CBCT technologies, either with or without prior images, to reconstruct a series of 3D CBCT images from a regular CBCT scan, corresponding to different breathing phases or time points during the scan. For the technology using prior images, we used 4DCT as training data. A deformable image registration is first carried out between among 4DCT images resulting in deformation vector fields (DVF). These DVFs are represented by a few eigenvectors and coefficients obtained from principal component analysis (PCA). The volumetric reconstruction from a CBCT projection is realized by optimizing the PCA coefficients such that the computed projection matches the measured CBCT projection. For the technology without prior images, we developed a novel algorithm to reconstruct a 3D image corresponding to each CBCT projection, by effectively utilizing the underlying temporal coherence, such as periodicity or repetition, in all reconstructed 3D images. Assuming each column of the matrix U represents a CBCT image to be reconstructed and the total number of columns is the same as the number of projections, the central idea of our method is that U can be approximated well by a matrix whose rank is much smaller than the number of projections in the matrix factorization form $U = LR$. The number of columns for the matrix L constrains the rank of approximation and hence implicitly imposing a temporal coherence condition among all the images in cine-CBCT. We further impose desired image properties by enforcing sparsity of the tight wavelet frame transform of L . In this matrix factorization formulation both the low rank approximation and the sparse representation in wavelet transform domain reduces the true degree of freedom of U significantly. A split Bregman method is used to solve the problem.

JOINT SYMPOSIUM: ESTRO-GEC-ESTRO: BRACHY-THERAPY - GYNAECOLOGY

SP-0635

Role of image-guided adaptive brachytherapy in the treatment of cervical cancer

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The standard treatment of locally advanced cervical cancer consists of external beam radiotherapy with concomitant cisplatin followed by intracavitary brachytherapy (BT). For decades BT has most often been based on radiographs with the BT dose prescribed to point A. In 2005 an adaptive target concept for BT based on 3D imaging was introduced by the GYN GEC-ESTRO working group addressing both the tumour extend at diagnosis - the Intermediate Risk Clinical Target Volume (IR CTV) as well as the remaining tumour at time of BT - the High Risk Clinical Target Volume (HR CTV).

With the introduction of Image Guided Adaptive BT (IGABT) it is possible to move from point A to 3D dose volume prescription in terms of dose volume histogram (DVH) parameters. Furthermore, dose optimisation can be performed with modifications of standard loading patterns leading to an individually sculpted pear-shaped isodose tailored to the target and organs (OAR) at risk at time of BT.

However, dose optimisation based on intracavitary (IC) BT applicators have limitations especially in large tumours with extensive parametrial involvement remaining at time of BT or in cases with unfavourable combination of topography between the HR CTV and the OAR. A solution is to add an interstitial (IS) component to the basic IC applicator. Studies with limited number of patients have shown that combined IC/IS BT improve the DVH parameters, but larger studies on clinical feasibility are sparse and widespread implementation of the IC/IS technique is so far limited.

At present, promising mono-institutional data on IGABT for cervical cancer with high local control rates and limited morbidity have been

published. Furthermore, several studies have established dose constraints for target as well as OAR.

In order to achieve more experience on IGABT for cervical cancer, large-scale multi-studies such as the EMBRACE-study and RETROEMBRACE-study have been initiated. During the next years, data will mature for analysis and serve as benchmark for future IGABT in cervical cancer.

The purpose of this lecture is to describe and explain the basic components behind the recommendations from the GYN GEC-ESTRO working group. Furthermore, it is aimed to review the literature on IGABT and describe outcome in terms of local control, survival and morbidity from published mono-institutional series of patients. Finally, it is aimed to describe the future directions in IGABT for cervical cancer.

SP-0636

Physics aspects of treatment planning for intracavitary w/o interstitial techniques in cervical cancer

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For cervical cancer interstitial and intracavitary brachytherapy techniques are an option to treat the tumour sufficient by keeping the traditional pear-shaped isodose distribution. Improvement of target coverage and organs at risk sparing is determined by DVH parameters D90, D98 (D100) for the target and D2cc, D0.1cc for OAR. The major limitation in the optimization process is the dose to the adjacent OAR's like sigmoid, rectum and bladder. As the pear-shaped dose distribution based on the intracavitary applicator can be enlarged to a certain extend only, additional needles are useful to push the isodose lines into the needed direction (Parametrium- pelvic side wall).

The selection of the adequate application technique depends on the size and shape of the target volume at time of brachytherapy (after EBRT). With intracavitary techniques tumours which are limited to the cervix can be appropriately treated. Nevertheless, small tumours with unfavourable topographies within the pelvis (narrow anatomies with only a small distance from the tumour to the OAR bladder, rectum or sigmoid) may benefit from the use of additional needles. Over the last years "standard" intracavitary applicators have been modified in a way to allow insertion of needles through guiding holes, i.e. the "vaginal" part of the applicator (ring, ovoid or mould) serves as and interstitial template which is attached to the cervix. Other techniques use vaginal cylinders including oblique guiding holes or templates like the MUPIT or Syed. For vaginal cancer intravaginal templates exist. In interstitial treatment planning, traditionally, the Paris System rules are kept in mind. Different tools like inverse planning, graphical drag-and-drop of isodose lines and other optimization techniques are available but should be handled with caution. The final dose distribution including high dose volumes should always be checked before irradiation. In situation of complex tumour configurations pre-planning of the application technique with 3D imaging increases the quality of the implant and of the final treatment plan.

SP-0637

The role of the radiation technologist in the Brachytherapy (BT) Service at the Gustave Roussy Institute

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The BT Service, in terms of material, is composed of five pulsed dose rate (PDR) and one high dose rate (HDR) afterloaders. Interstitial, endocavitary and endoluminal BT are performed depending on the type and tumor localizations. The team consists of physicians, residents, medical physicists and radiation therapy technologists (RTTs). The presentation purpose is to describe the role and the work of an RTT in the treatment of patients with cervix cancers in our institute.

Role of RTT:

RTT plays a major role in a BT service. Essential for the team cohesion, she is working at the interface of the radiation oncologist, medical physicist, and patient. Present in all steps of the treatment, she participates to the consultation, preparation, implantation, dosimetry and treatment compliance. In order to improve the overall treatment conditions, a pre-therapeutic consultation is systematically performed by the RTT. The aim is to answer questions about hospitalization, radioactivity, management of pain and treatment itself. A picture book describing the different steps of the treatment was designed by RTT. This helps and allows a better understanding for patients.

The technique used in our institute for the cervix BT consists of the vaginal mould technique. For each patient, a customized vaginal mould is created from a vaginal impression. The mould applicator